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Kiewit

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[54] **WHEELCHAIR WHEEL CAMBERING APPARATUS**

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[21] Appl. No.: **520,831**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 312,531, Sep. 26, 1994, abandoned.

[51] **Int. Cl.**^{6} **B62M 1/14**; B62D 17/00

[52] **U.S. Cl.** **280/250.1**; 280/661

[58] **Field of Search** 280/250.1, 304.1, 280/647, 650, 657, 661; 180/907; 297/DIG. 4

[56] **References Cited**

U.S. PATENT DOCUMENTS

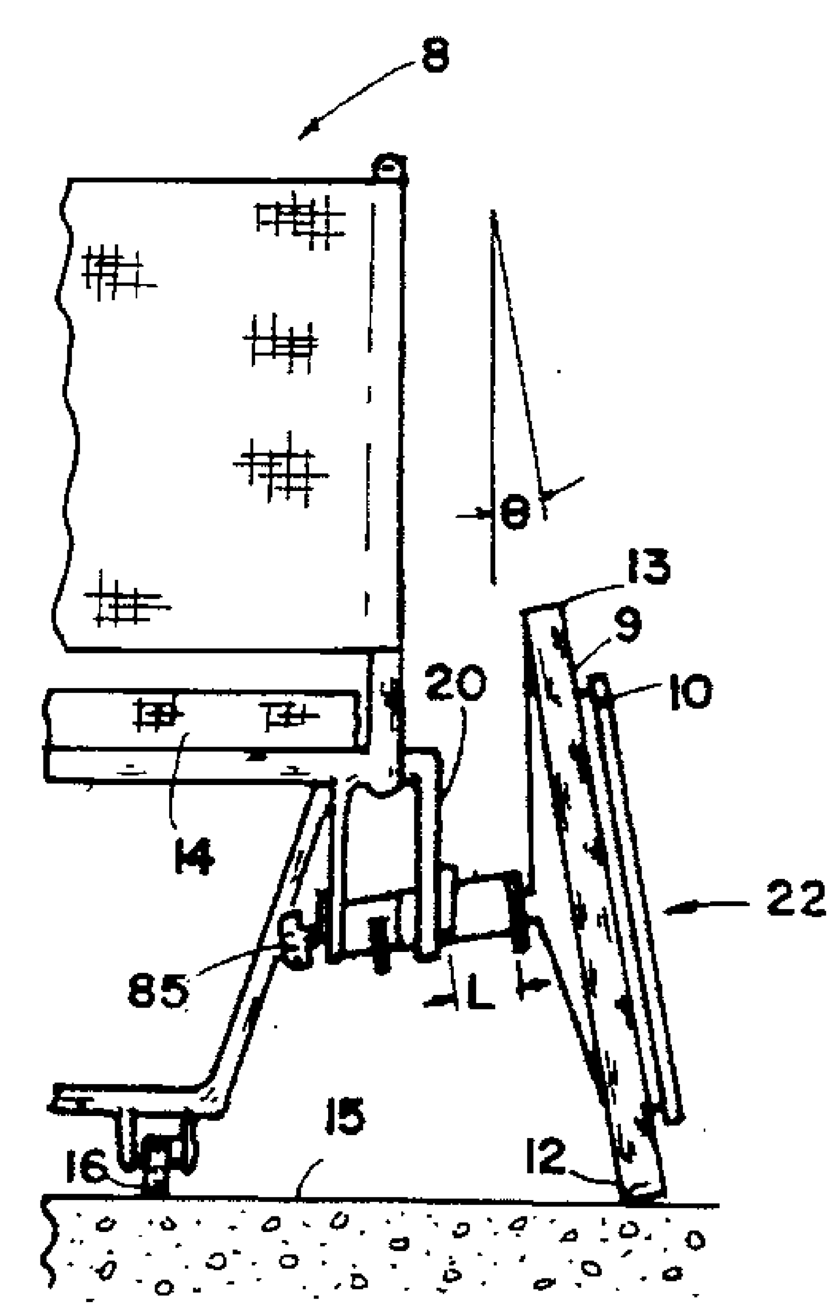
4,362,311	12/1982	Bergman	280/250.1
4,457,528	7/1984	Ichikawa et al.	280/250.1
4,506,901	3/1985	Tosti	280/250.1
4,758,013	7/1988	Agrillo	280/250.1
4,971,397	11/1990	Nichols et al.	301/110.5

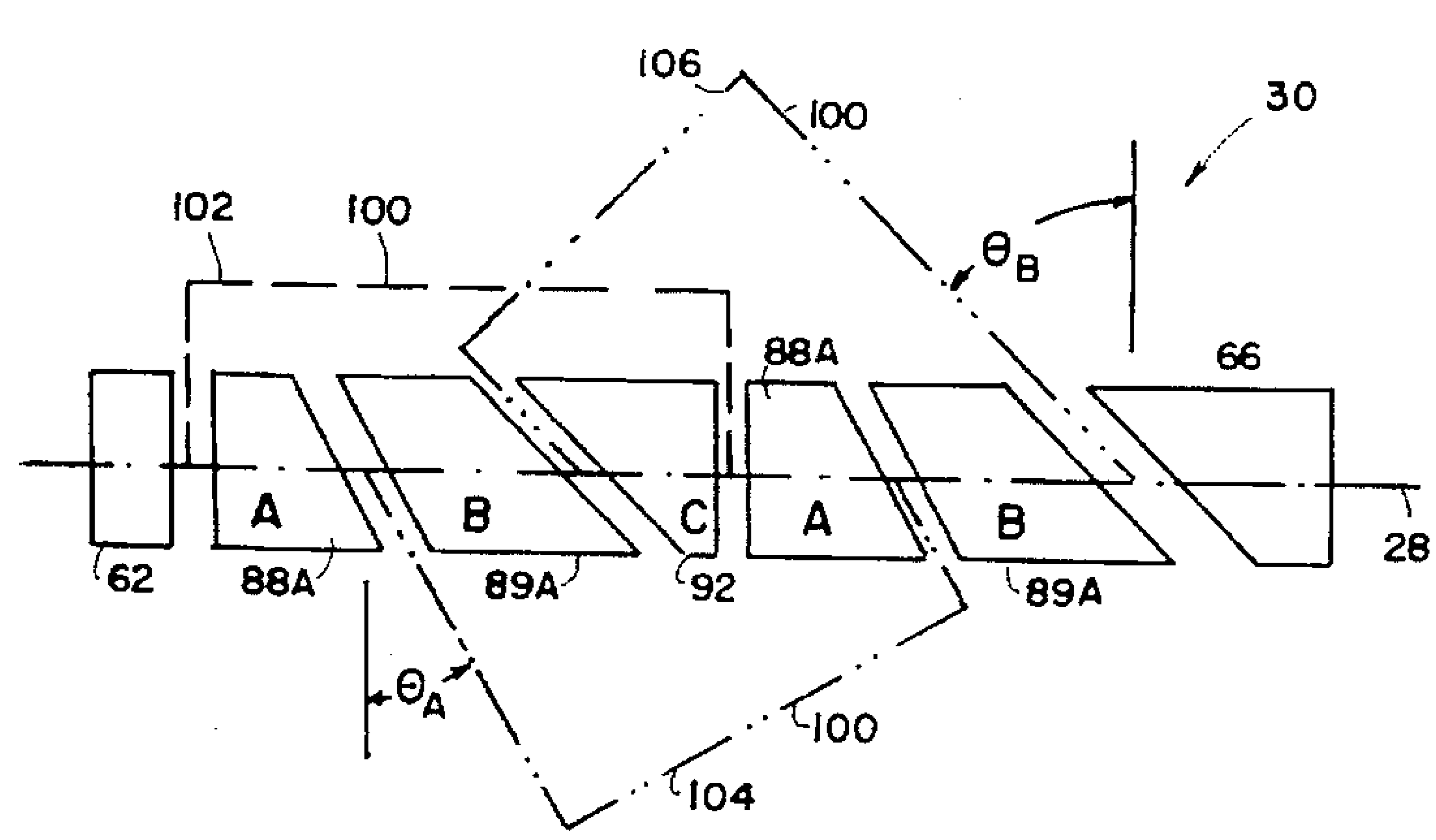
Primary Examiner—Brian L. Johnson
Assistant Examiner—Victor E. Johnson
Attorney, Agent, or Firm—David Kiewit

[57] **ABSTRACT**

The main wheels of a wheelchair are attached to the chair at a predetermined one of a plurality of camber angles differing by one or more predetermined angular measure(s). The apparatus comprises a bracket extending from the wheelchair's frame as well as a plurality of axle retainers disposed about and juxtaposed along the stub axle, the retainers used to mount the axle in the bracket. Switching from a first of two predetermined camber angles to the second requires removing the axle and retainers from the bracket, translating the axle either inboard or outboard (i.e., either toward or away from the center of the chair) by a predetermined amount, and reattaching the wheel to the chair. The operation may also involve adjusting the length of one or more of the bracket legs. Switching between camber angles preferably does not affect the height of the chair's seat or the position of the top of the wheels relative to the user's shoulders.

13 Claims, 9 Drawing Sheets





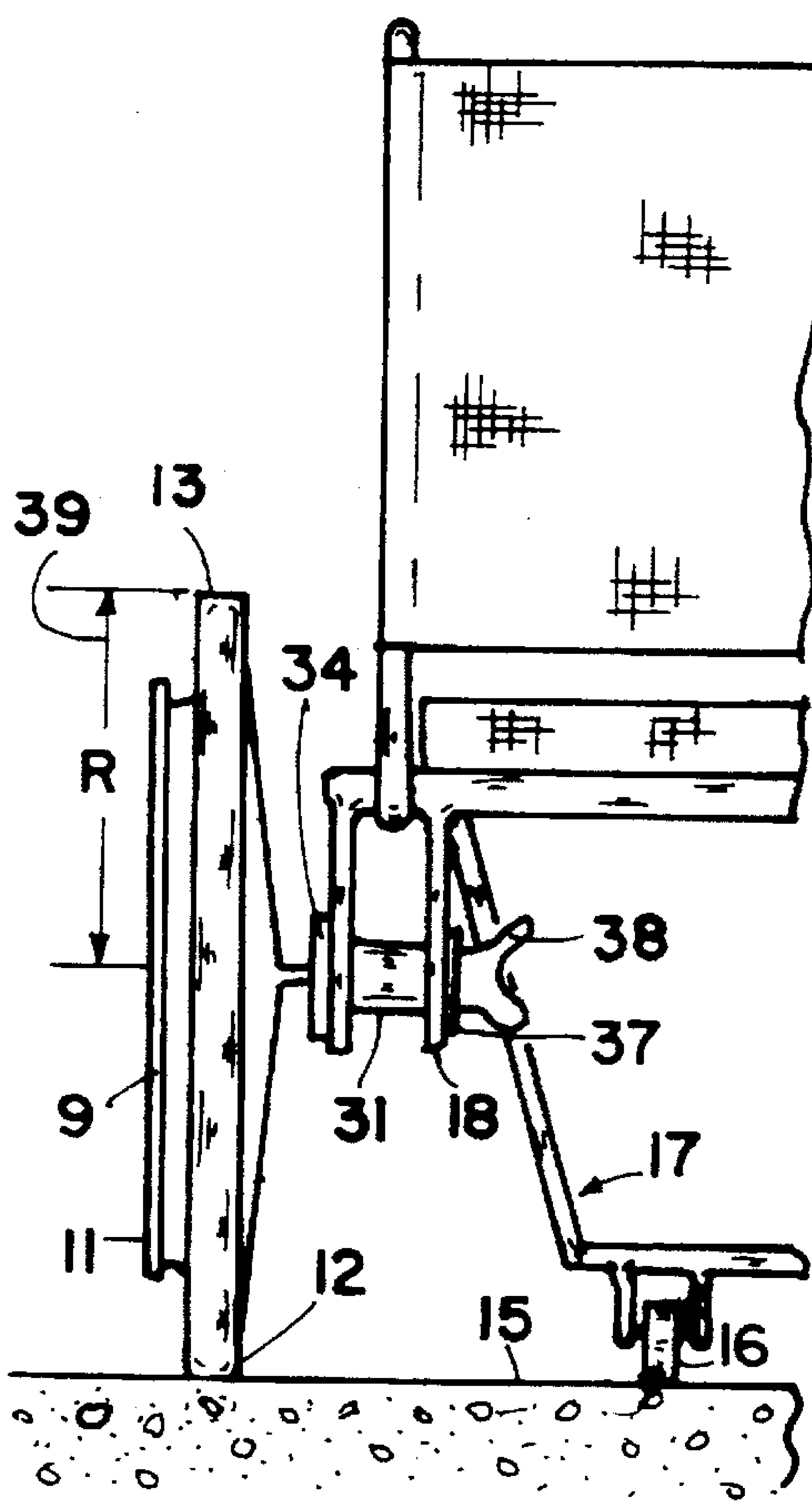


FIG. 1A
PRIOR ART

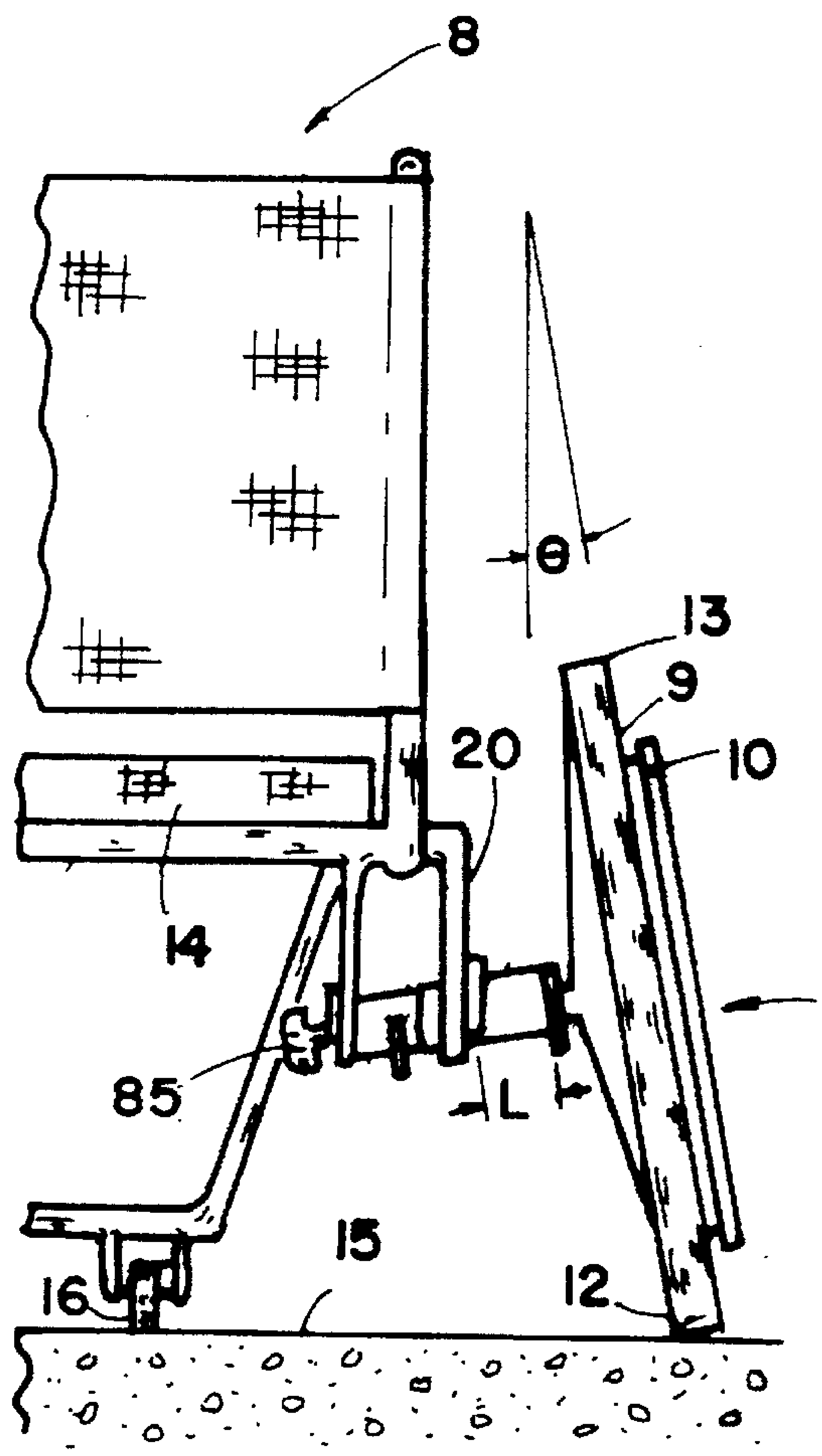
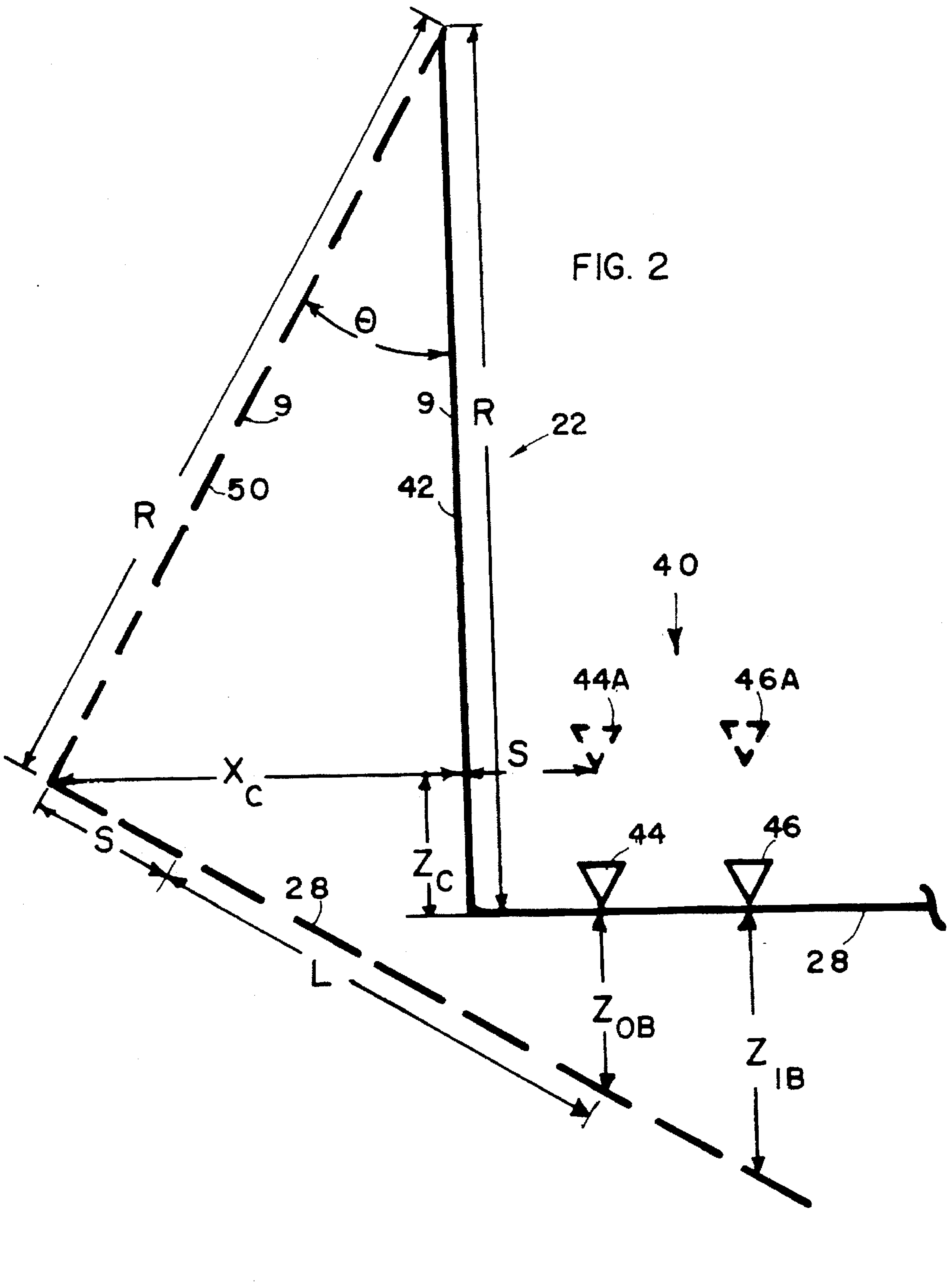


FIG. 1B

FIG. 2



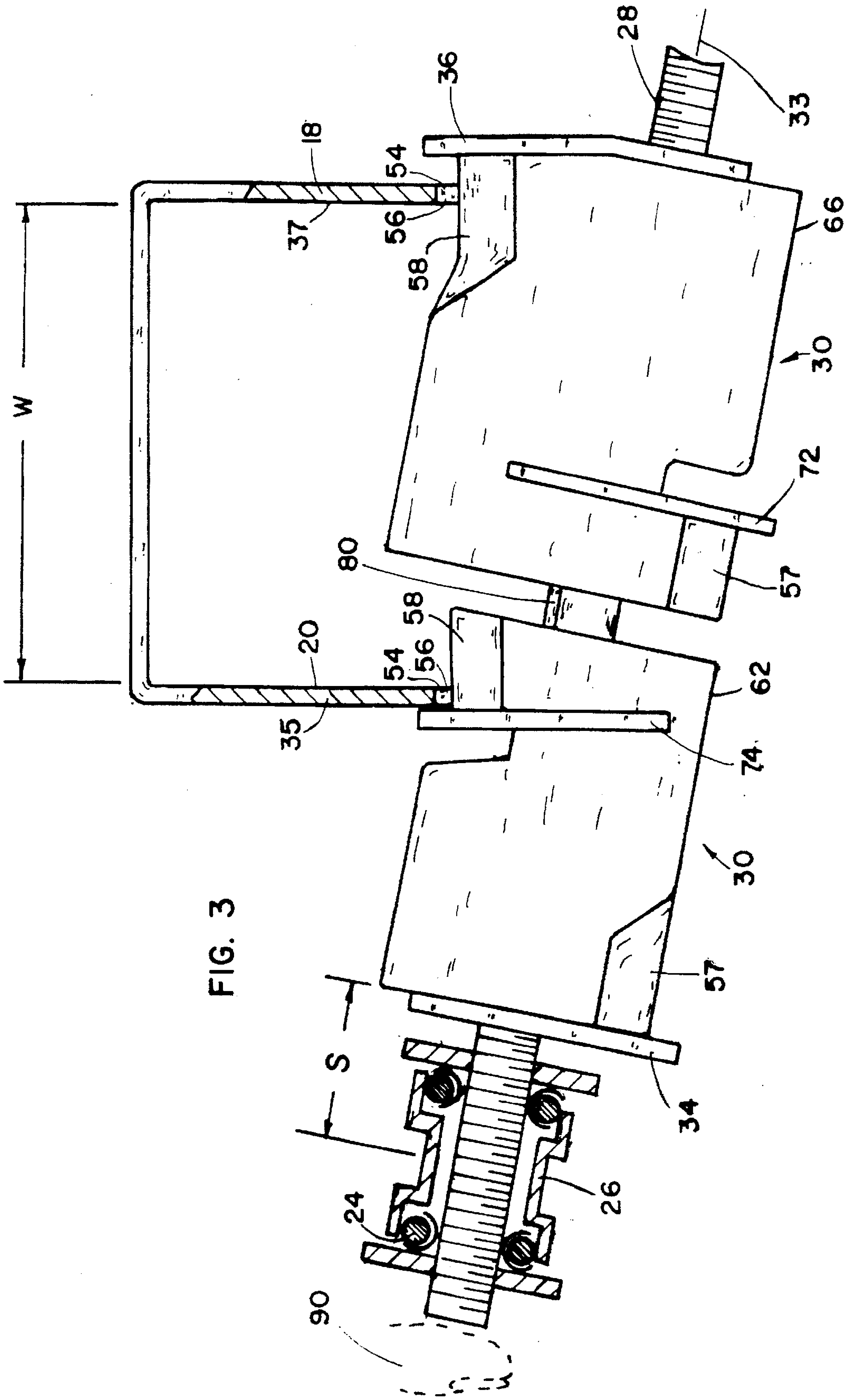
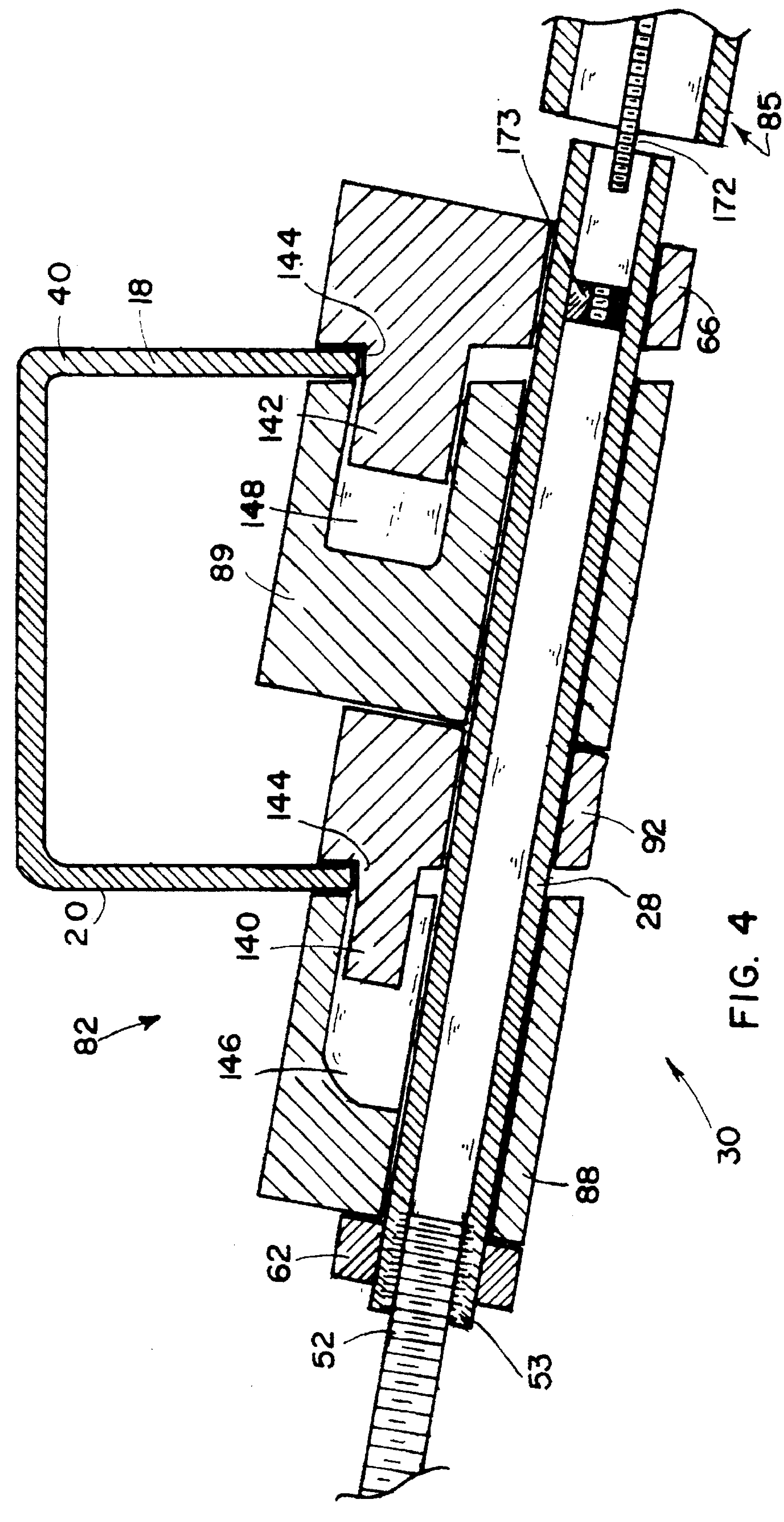

28
33
36
18
54
37
56
58
66
30
W
72
80
57
58
20
56
54
62
35
74
30
57
S
34
24
26
90

FIG. 3



40
18
144
173
85
172
66
142
148
89
144
92
28
20
140
82
146
30
88
62
52
53

FIG. 4

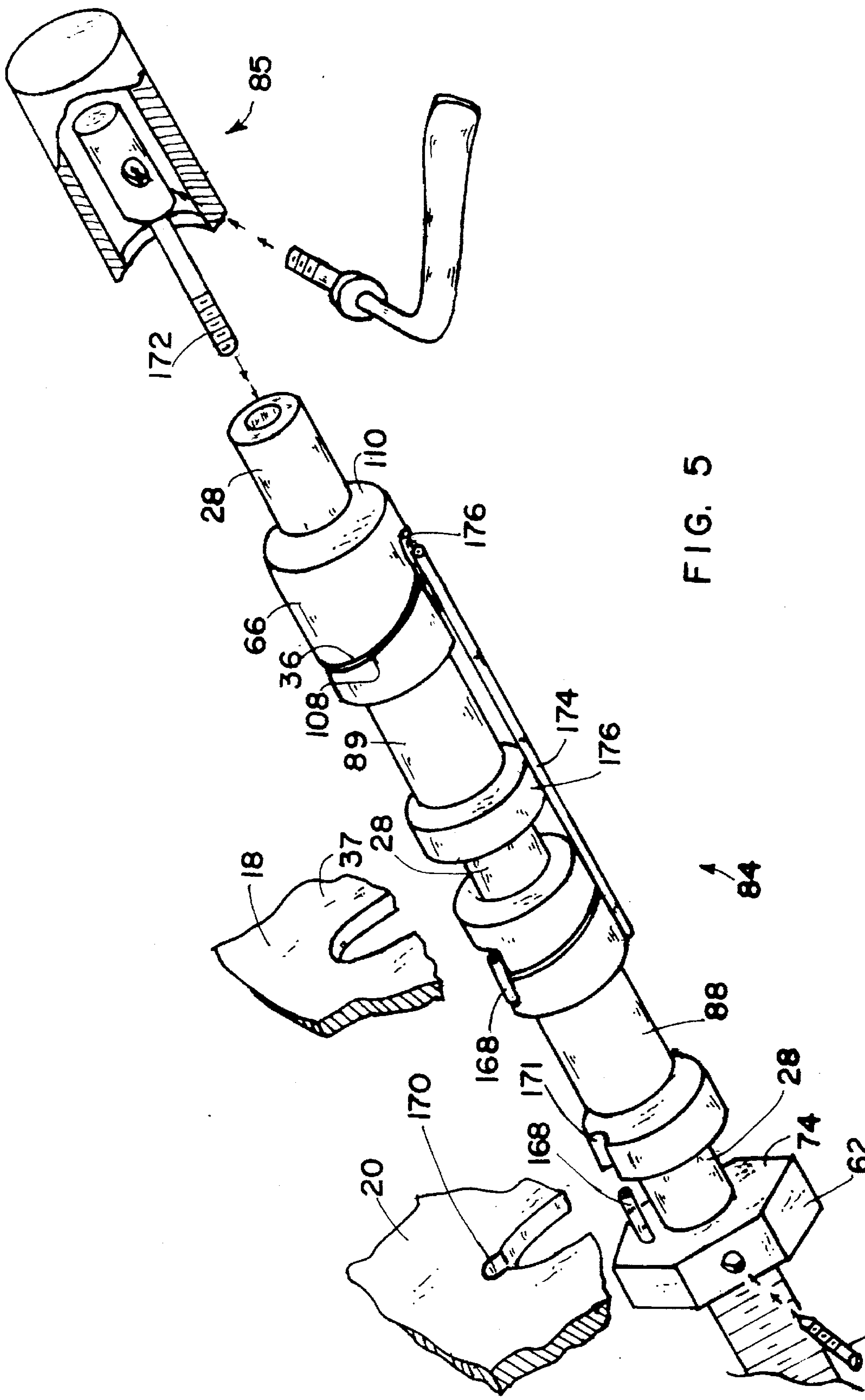

85
172
28
110
176
66
36
108
89
174
176
28
37
18
84
168
88
170
20
171
168
28
74
62
64

FIG. 5

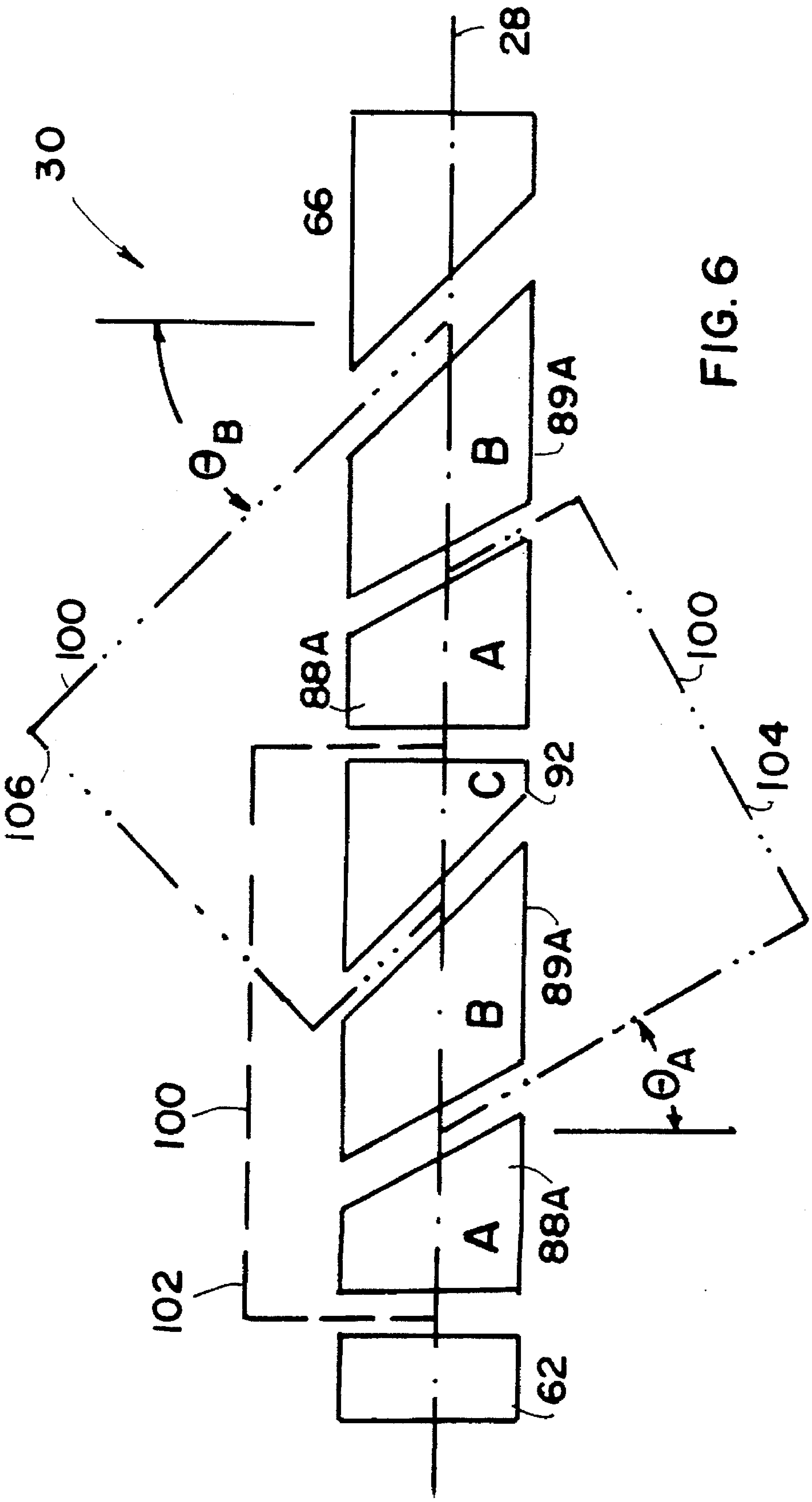


FIG. 6

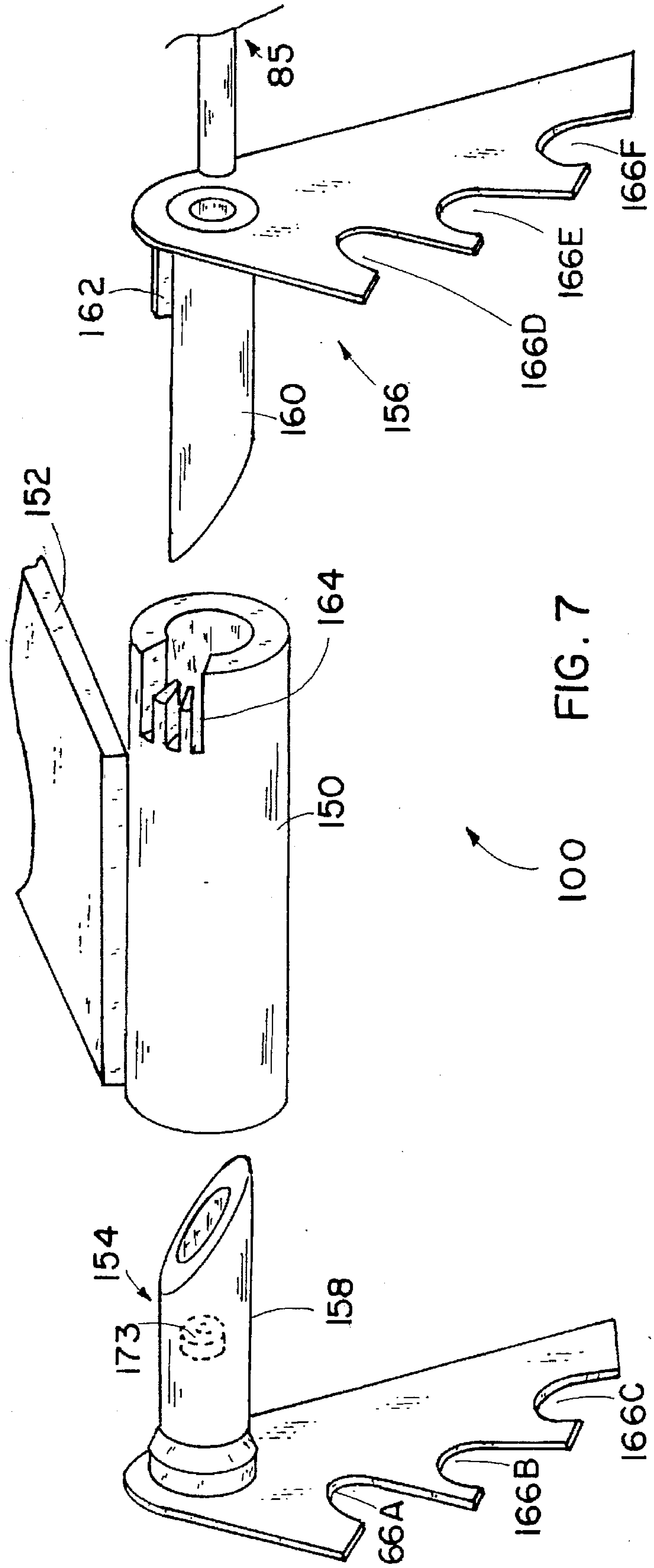

85
162
160
156
166D
166E
166F
152
164
150
100
154
173
158
166A
166B
166C

FIG. 7

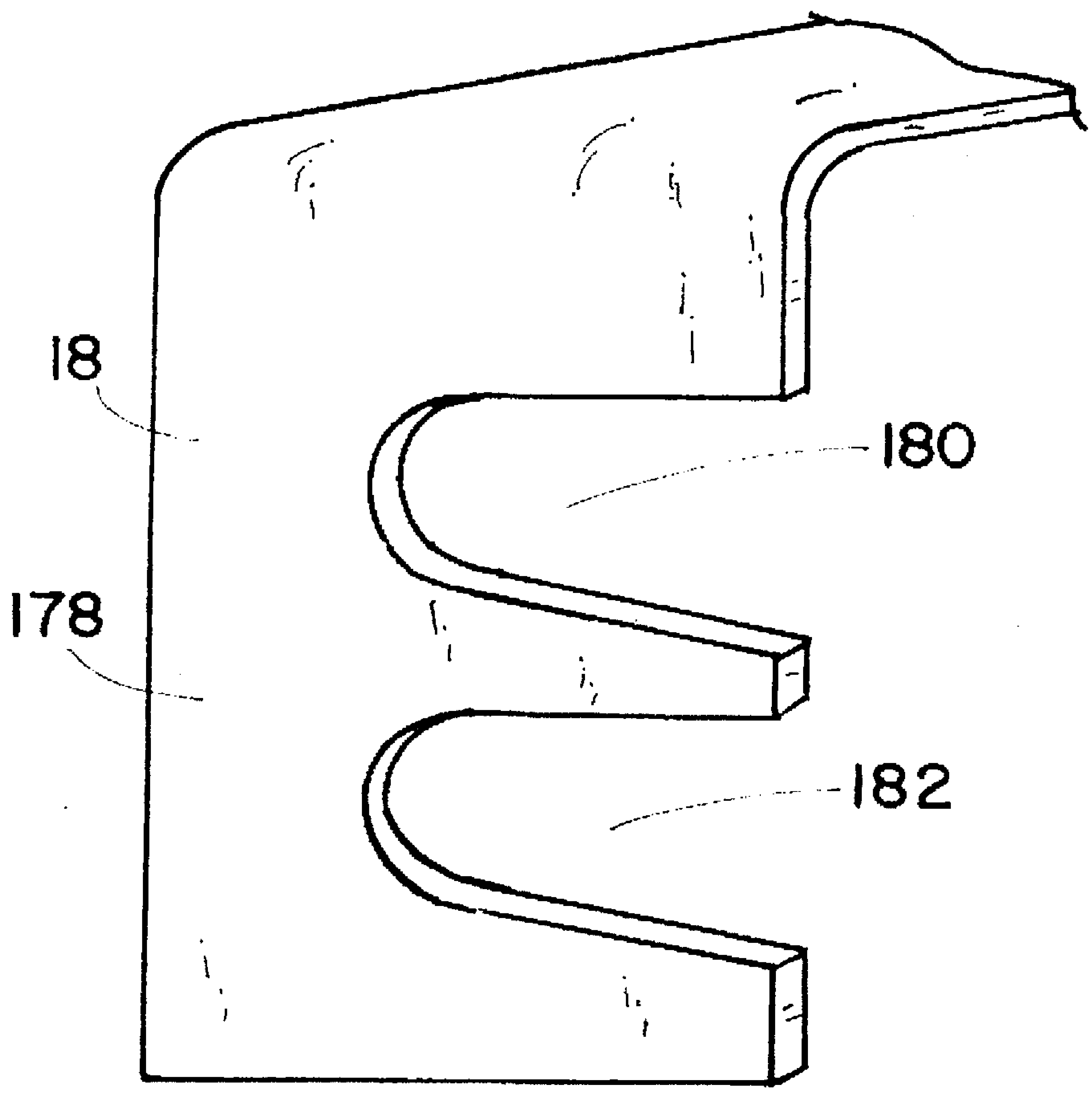
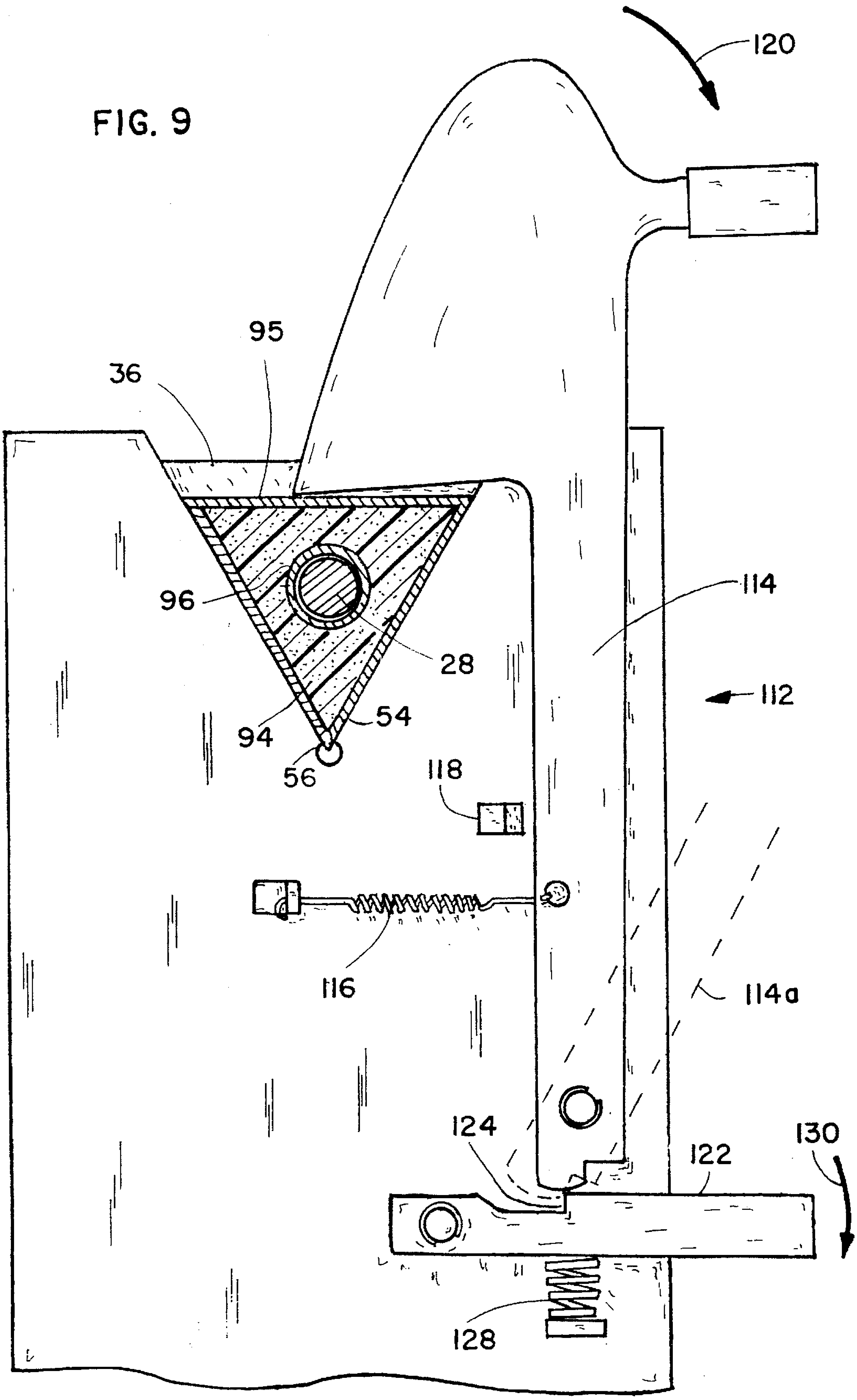


FIG. 8

FIG. 9



WHEELCHAIR WHEEL CAMBERING APPARATUS

This application is a continuation-in-part of the inventor's U.S. application Ser. No. 08/312,531, which was filed on Sep. 26, 1994, and which is now abandoned.

BACKGROUND OF THE INVENTION

If the large main wheels of a wheelchair are in a vertical plane (i.e., set at a 0° camber angle) the track width is minimized. This makes it easier for the chair to pass through narrow doorways. If, on the other hand, the wheels are cambered outward at the base by some angle, the increased track width improves lateral stability, which allows for sharper turns. Although prior art wheelchairs have been made with adjustable camber angles, resetting the camber angle of a chair is at best a laborious operation requiring considerable mechanical aptitude, a selection of hand tools, and a safe place to keep small semi-custom hardware items. Most prior art chairs are made with a single camber angle that is not adjustable.

The prior art of making a wheelchair with an adjustable main wheel camber angle comprises at least the following:

A widely used receiving socket for a stub axle is designed to be bolted to a wheelchair frame with four bolts. Shims (e.g., washers placed around two of the four bolts) are used to tilt the socket about a horizontal axis.

Friedrich, in U.S. Pat. No. 4,768,797, teaches an axle-receiving socket tiltable to one of a predetermined number of angles. Friedrich provides a plurality of vertically disposed sets of mounting holes on the side of a socket assembly. The holes are aligned so each set provides a different camber angle, and so that the mounting point of the wheel system is translated outward as the camber angle increases, which ensures that the top of the wheel, where the wheelchair user grasps the push rim, stays in the same position relative to the user's body. Friedrich's mounting system provides only for relatively small (e.g., three degrees of arc) changes in camber angle.

McWehty, in U.S. Pat. No. 5,060,962, teaches an improvement to the receiving socket mentioned above. McWehty provides a receiving socket assembly comprising an angled cambering sleeve member.

Robertson et al, in U.S. Pat. No. 5,131,672, teach a chair with a large uncambered bore in its frame. Pairs of plugs, each with its own internal cambered axle-receiving socket, are plugged into the uncambered bore to set the wheel camber angle. Robertson et al also provide a useful review of the variety of camber angles commonly employed and of wheelchair sports for which various camber angles are commonly used.

The art of demountably attaching a wheel to a wheelchair is also relevant to the present invention, particularly as it relates to light, rigid frame chairs used by wheelchair athletes. These chairs are designed with readily demountable wheels so that when the occupant of the chair transfers to an automobile, the frame and the wheels are separated before being loaded into the car. Two methods of wheel attachment for these chairs are in common use:

A threaded stub axle is screwed into a socket on the frame. This arrangement has proven unpopular with people who have misplaced a wrench and have been unable to get the chair into a car until after the wrench was found or replaced.

A hollow stub axle with a laterally protruding spring-biased ball is inserted into a socket on the frame (see, for example, FIG. 3 of U.S. Pat. No. 5,060,962)—i.e., the stub axle acts as a single-acting ball-lock pin. The exterior surface of the hollow stub axle must be lubricated. This surface, which is exposed when the wheel is demounted, stains car upholstery.

Bergman, in U.S. Pat. No. 4,362,311, teaches a wheelchair in which stub axles extending from the hubs of main wheels are received in brackets having cooperating bifurcated legs.

Agrillo, in U.S. Pat. No. 4,758,013, teaches a wheelchair in which a collection of tubular members surrounding a stub axle are received in bifurcated slots extending from the wheelchair's frame.

SUMMARY OF THE INVENTION

A preferred embodiment of the invention provides apparatus for attaching a wheel system to a wheelchair at a predetermined one of a plurality of camber angles, where the angles differ by one or more predetermined angular measure (s), and where the wheel system comprises a wheel with bearings in a hub thereof and a stub axle (i.e., a non-rotating axle extending outwards from one side of the wheel). The apparatus comprises a bracket fixedly attached to, or integrally formed with, the wheelchair's frame as well as a plurality of axle retainers disposed about and juxtaposed along the stub axle, the retainers used to mount the axle in the bracket.

A preferred arrangement comprises three bushings slideably juxtaposed about a stub axle or extension thereof, one of the two possible pairings of the three bushings received in a bracket in each of two camber settings. Switching from a first of two predetermined camber angles to the second with this arrangement is a matter of removing the axle from the bracket, tilting and translating the axle either inboard or outboard (i.e., either toward or away from the center of the chair) by a predetermined amount, and reattaching the wheel to the chair.

The invention also provides a method and apparatus for attaching a wheel system to a wheelchair in which: a) there are no exposed lubricated surfaces of the apparatus to dirty a user's hands or to stain his or her automobile upholstery; and b) there are no tools or separate parts that need be carried by the user.

Some embodiments of the invention provide a spring-biased safety latch retaining a stub axle and an associated retainer in a mounting bracket. This latch provides a safety mechanism in the event that a main retaining means fails. The latch also captures and holds the axle in an approximately correct position in the bracket while the user shifts his or her hand positions during the process of attaching or demounting the wheel.

It is an overall object of the invention to provide means by which a wheelchair user can conveniently use the same chair for wheelchair sports that he or she uses inside a dwelling.

It is an additional object of the invention to allow the user of a wheelchair to easily and reproducibly select one of a plurality of camber angles for the main wheels of the chair.

It is a specific object of the invention to provide wheel attaching means allowing the main wheels of a wheelchair to be mounted to the chair at either of two predetermined camber angles, where the mounting operation is carried out without the use of separately carried tools.

It is an additional object of the invention to provide a wheel attaching method and apparatus for a wheelchair in which the detached wheel and stub axle have no exposed lubricated surface.

DESCRIPTION OF THE DRAWING

FIG. 1A of the drawing is a rear elevational view of the left side of a wheelchair having its main wheel set in a vertical plane.

FIG. 1B of the drawing is a coordinated rear elevational view of the right side of the wheelchair of FIG. 1A, where the right main wheel is cambered by an angle designated as θ.

FIG. 2 of the drawing is a geometrical schematic of dimensional changes occurring on re-cambering a wheel while holding the top of the wheel at a fixed point in space.

FIG. 3 of the drawing is a partly cut-away rear elevational view of an embodiment of the invention in which axle-retaining elements with slanted bearing surfaces clamp a wheel system to a bracket having two legs of fixed and equal lengths.

FIG. 4 of the drawing is a cross-sectional view of a preferred embodiment of the invention in which vertical adjustments associated with re-cambering are provided by means of bearing surfaces disposed on ones of a set of bushings juxtaposed along an axle, the bearing surfaces radially displaced from the axis of the axle by predetermined amounts.

FIG. 5 of the drawing is a partially exploded and partially cut-away view of an array of tubular elements usable with a variable leg length bracket to select one of two predetermined camber angles.

FIG. 6 of the drawing is a schematic view of a plurality of tubular elements used with a variable leg length bracket to select one of three predetermined camber angles.

FIG. 7 of the drawing is an exploded perspective view of a variable leg length bracket.

FIG. 8 of the drawing is an elevational view of a bracket leg having two laterally bifurcated slots.

FIG. 9 of the drawing is a partial elevational view of the outboard face of an inboard leg of a bracket showing a latching mechanism retaining a three-lobed tubular element.

DETAILED DESCRIPTION

Turning to FIGS. 1A and 1B, one finds coordinated rear elevational views of a wheelchair **8** with one main wheel **9** set in a vertical plane and the other main wheel **9** cambered outward at the bottom **12** and inward at the top **13** by an angle θ. Because the two camber angles would not be used on one chair **8** at one time, and because a change in camber angle θ may be accompanied by a change in the height of the seat **14** above the terrain **15**, FIG. 1A and FIG. 1B show a composite view. The chair **8** of FIGS. 1A and 1B includes a frame **17** from which an inboard bracket leg **18** and an outboard bracket leg **20** depend. A wheel system **22** including a main wheel **9** (preferably with a sealed bearing **24** in its hub **26** so that it can rotate about a stub axle **28**) is clamped to bracket legs **18**, **20** depending from the frame **17** below the seat **14**. The camber angle θ is set with the aid of tubular axle retaining elements **30**, as will be subsequently herein disclosed.

Although a tubular axle retainer **30** may be symmetrical about the axle **28** and used with bracket legs **18**, **20** having equal length, so that the camber angle of the wheel **9** is the always the same (e.g., the uncambered wheel **11** of FIG. 1A that is attached to the chair **8** by means including a single axle retaining tubular element **31**), in a manner similar to that depicted by Agrillio in U.S. Pat. No. 4,758,013 the present invention employs a plurality of axle retainers **30** to change the camber angle θ by demounting the wheel system **22**, moving it inboard or outboard, and reattaching it to the wheelchair **8** by means of a bracket **40**.

The camber change is preferably accompanied by a translation of the center of the wheel **9**. If this is not done, the distance between the top **13** of the wheel **9** and the frame **17** will change. Since the distance between the tops **13** of the wheels **9** is matched to the user's shoulder width, this distance is preferably kept constant while the camber angle θ is varied. Thus, an ideal recambering operation on a wheelchair **8** will rotate the wheel system **22** about the top **13** of the wheel **9**, or other nearby point such as the top of the push rim **10**. The effective radius, R, of the wheel system **22** is normally measured from the center **33** of the axle **28** to the outermost part of a tire since the spacing between the tire sidewall and the side of the chair **8** is usually the critical controlled dimension.

The geometry of this situation is shown schematically in FIG. 2, where the initial setting of the wheel system **22** is indicated with solid bold lines **42** contacting a bracket **40** (indicated by triangles **44**, **46**) which has a minimum width denoted as W, the minimum width occurring when the bracket legs are flexed during a clamping operation. A second, cambered, setting of the wheel system **22** is indicated with dashed bold lines **50**. In the interest of clarity of presentation, the cambering angular change, θ, depicted in FIG. 2 is greater than the maximum change of fifteen degrees or so used in practice. In FIG. 2 the effective radius of the wheel system **22** is labeled with a capital R; the standoff spacing (e.g., measured from the center of the hub **26** to the outboard leg **20** of a bracket) is labeled with a capital S; the horizontal and vertical displacements of the center of the hub **26** are labeled x_C and z_C, respectively; and the vertical distances between the outboard leg **18** of the bracket **40** and the inboard leg **20** of the bracket **40** are denoted as z_C, z_{OB}, and z_{IB}, respectively.

Because the horizontal position of the outboard bracket leg **20** remains fixed, the stub axle **28** is translated along its axis by a distance denoted as "L". That is, L is the distance measured along the axis **33** of the axle **28** between a first point on the axle **28** immediately below the outboard bracket leg **20** when the wheel **22** is set at a first camber angle and a second point on the axle immediately below the outboard bracket leg **20** when the wheel **22** is set at a second camber angle. If the change in θ is small, this shift is negligible. For a significant change in camber (e.g., changing θ by 10° in going from an initial setting of 2° to a final setting of 12°) the required shift is about 5.3 cm for a wheel with an effective radius **39** of thirty centimeters. A trigonometric analysis of FIG. 2 shows L is equal to $R\tan\theta+S(\sec\theta-1)$. For reasonable values of the standoff distance, S, (e.g., S=5 cm), the second term in this expression is small, and L can often be approximated by $R\tan\theta$.

Increasing the camber angle, θ, can drop the rear of the seat **14** closer to the ground by the amount indicated as z_C in FIG. 2 and thereby change the rake angle of the stem of the front caster wheels **16**. This affects the handling characteristics of the chair **8**, and may be deleterious if the magnitude of the changes are great enough. A vertical change in the effective bracket position compensating for this drop and thereby keeping the seat **14** level is depicted in FIG. 2 by phantom triangles **44A**, **46A**.

The apparatus of the invention provides both for translating the axle **28** along its axis, and for adjusting the effective lengths of the inboard **18** and outboard **20** legs of a bracket **40** used to hold the axle **28**. This change in effective length may be done by physically changing the lengths of the legs **18**, **20**; by providing bearing surface portions **57**, **58**, **140**, **142** on various of the tubular elements **30** (where the bearing surface portions **57**, **58**, **140**, **142** are radially displaced from the axis **33** of the axle **28**); or by combinations of the two techniques. The stub axle **28**, as hereinafter described, may be a single element (e.g., a 7/16–20 bolt fitted within an inner sleeve through the hub **26**, as is common in the prior art) or may be formed as a subassembly in which a first stub axle element **52** passing through the hub **26** is joined to a coaxial second axle element **53** (e.g., the arrangement depicted in FIG. **4** where an externally threaded first element **52** screws into a coaxial hollow second axle element **53**).

As can be seen from the schematic of FIG. **2**, the bracket legs **18**, **20** need to increase in length by the amounts z_{OB}, and z_{IB}, respectively, to accommodate the cambered axle. An additional length change of magnitude z_C may also be used to compensate for the height change associated with the change in camber angle. A trigonometric analysis of FIG. **2** indicates that z_{OB} is equal to $2z_C$+Stanθ, and z_{IB} is equal to z_{OB}+Wtanθ.

It will be appreciated that in some cases a designer may choose to ignore one or another of these shifts and accept small changes in the height of the seat **14**, rake of the caster **16**, etc. Such approximations may provide benefits such as lower cost or lower weight that render the dimensional inaccuracies acceptable. Thus, although the camber re-setting operation appears to call for changes in the height of both bracket legs **18**, **20**, providing an adjustable leg only at the inboard position may be adequate. Alternately, in cases where some lateral shifting of the top of the wheel **13** is tolerable, one could configure the apparatus of the invention with a single adjustable leg as the outboard bracket leg **20**.

In one embodiment **60** of the invention, shown in FIG. **3**, the bracket **40** has two depending bifurcated legs **18**, **20** in which a bifurcating, downward-opening slot **54** has a relieved vee-shaped cut or surface **56** at its upper end. The slot **54** receives corresponding bearing surfaces **57**, **58** formed on an exterior surface of a tubular axle retainer **30**. The embodiment **60** is an example of one in which the bracket legs **18**, **20** are of fixed length and all the dimensional changes are made by changing the radial distance between the axis of the axle **28** and the bearing surfaces **57**.

The embodiment **60** of FIG. **3** uses two tubular retainers **30**. One of these, hereinafter referred to as the "outboard nut" **62** is affixed to and prohibited from sliding along the axle **28** at a predetermined "standoff" distance, S, from the hub **26** of the wheel **9**. The second tubular member in this embodiment **60** is an inboard bushing **66**, which slides to and fro along the axle **28** during clamping and demounting. The dimensions of the nut **62** and bushing **66** may be chosen so that the distances between pairs of flanges **36**, **74** and **34**, **72** are the same and are slightly less than the outer width of the bracket **40**, so that a clamping means **85** on the inboard end of the axle **28** can clamp the bracket, which is preferably highly rigid in the embodiment **60** of FIG. **3**, between the nut **62** and bushing **66**.

The inboard bushing **66** and outboard nut **62** may have one or more flanges **34**, **36**, **72**, **74** (which may be attached to the tubular elements **30** by a variety of known methods, or may be integrally formed therewith). The outboard flanges **34**, **72** on the nut **62** and bushing **66**, respectively, are Generally more upstanding than are the corresponding inboard flanges **74**, **36**. For an uncambered setting the outboard flanges **34**, **72**, which are perpendicular to the axle **28** engage the exterior faces **35**, **37** of equal length bracket legs **18**, **20**. For the cambered case shown in FIG. **3**, the wheel **9** is translated outboard, the nut **62** and bushing **66** are rotated 180° about the axle **28**, and the corresponding inboard flanges **74**, **36** engage exterior faces **35**, **37** of bracket legs **18**, **20**.

BACKGROUND OF THE INVENTION

In this embodiment **60** each tubular member **30** comprises a plurality of bearing surface portions **57**, **58** associated respectively with a corresponding plurality of camber settings. The bearing surface portions **57**, **58** on both nut **62** and bushing **66** are tilted with respect to each other by the angular measure associated with the desired camber change, and the radial distances from the axle axis **33** to those segments of the bearing surface portions **57**, **58** that are immediately adjacent the flanges **34**, **36**, **72**, **74** are chosen to provide the desired camber angle.

The less upstanding flanges **74**, **36** are tilted with respect to the corresponding upstanding flanges **34**, **72** by an angular measure equal to the desired change in camber angle. The preferred lateral shift is provided by appropriately spacing ones of the flanges **34**, **36**, **72**, **74** along the axis **33** of the axle **28**. This is done by setting the spacing L to be equal to the distance between two points where planes including the pair of bracket-engaging faces of the paired flanges (**34**, **74** and **36**, **72**) intercept the axle axis **33**.

In order to ensure that properly paired ones of the bearing surfaces **57**, **58** engage the bracket **40**, the bushing **66** is preferably prohibited from rotating about the axle **28** independently of the nut **62**. A variety of means are known for allowing the bushing **66** to slide to and fro along the axle **28** while maintaining a constant rotational orientation with respect to the nut **62**. These include, inter alia, the key **174** and keyway **176** arrangement shown in FIG. **5** and the splined shaft **80** of FIG. **3**.

Several preferred embodiments **82**, **84** of the invention provide superior clamping by using structures mechanically analogous to clamping a bicycle wheel with a fixed axle length into a frame fork. The effective clampable bicycle axle length is normally defined by stop nuts, external to the wheel's axle bearings, on which the inner faces of the legs of the frame fork bear. This use of a fixed, essentially rigid, axle clamps each fork leg separately and allows for flexibility in the fork. As noted supra, the embodiment **60** of FIG. **3** requires a rigid bracket **40**—if either of the legs **18**, **20** of the bracket **40** flex toward the other leg **20**, **18**, the axle **28** may be released from the bracket **40**.

Turning now to FIG. **4**, one finds a cross-sectional view of a preferred embodiment **82** of the invention comprising four bushings **66**, **88**, **89**, **89** and clamping means **62**, **85**, all disposed about a stub axle **28** and cooperating with a set of bracket legs **18**, **20** having predetermined and equal lengths, to clamp the axle **28** into either of two settings. An important feature of the preferred embodiments **82**, **84** is the provision of two translational bushings **88**, **89** (each of which has a length equal to the chosen axial translation, L) and a middle bushing **92**. In the uncambered setting the outboard translational bushing **88** and the middle bushing **92** are captured intermediate the legs **18**, **20** of the bracket **40**. In the cambered setting depicted in FIG. **4** the middle bushing **92** and the inboard translational bushing **89** are similarly captured while the outboard translational bushing **88** is outboard of the outboard bracket leg **20**, thus providing the requisite axial translation. Because the lengths of the two translational bushings **88**, **89** are equal and the middle bushing **92** is captured within the bracket in both settings, it is clear that the preferred embodiments **82**, **84** provide a predetermined clampable length equal to the sum of the axial displacement, L, and the length of the middle bushing **92**. This clampable length sets the minimum value, W, of the inside width of the bracket **40**, which may comprise legs **18**, **20** having appreciable flexibility for movement in an inboard or outboard direction (e.g., similar to the flexibility of the front fork of a bicycle that allows its legs to move inward and outward during clamping and unclamping operations).

Other arrangements can be made of tubular members **30** having lengths chosen so that combinations of the elements **30** provide a predetermined clampable length, each combination associated with a different one of a plurality of camber angles. Although the foregoing discussion has focused on what is expected to be the most common case in which a choice is made between one of two camber settings, other arrangements can permit three or more camber angles to be used. Turning now to FIG. **6**, one finds a schematic depiction (in which artificially large cambering angles are used for clarity of presentation) of an array of tubular elements **30** usable with a variable leg length bracket **100** to allow selection of one of three camber angles. The array of tubular elements **30** of FIG. **6** comprises an outboard nut **62**; a first pair of translational bushings **88A** (labeled "A") having the same appropriately chosen length and having one set of pair of bracket-engaging flange faces perpendicular to the axis of the axle **28** (shown in FIG. **6** with a dash-dot line) and a second set of pair of flange faces tilted away therefrom by a first camber angle, θ_A; a second pair of translational bushings **89A** (labeled "B") both having a second appropriately chosen length and both having a first set of flange faces tilted by θ_A and a second set of flange faces tilted by a second camber angle, θ_B; a middle bushing **92** (labeled "C") having one perpendicular flange face and one flange face tilted at θ_B; and an inboard bushing **66** having an appropriately tilted outboard-facing flange face. The uncambered setting of the bracket **40**, where the pair of bracket-engaging flange faces are tilted at zero degrees from a line perpendicular to the axle, is depicted by dashed phantom line **102**. In this $\theta=0$ setting the bracket **40** captures elements labeled A, B, and C. In the setting cambered at θ_A (indicated with double-dotted dashed line **104**) the bracket **40** captures B, C and A. In the setting cambered at θ_B (denoted with triple-dotted dashed line **106**) the bracket **40** captures C, A, and B. That is, all three settings provide that the bracket **40** captures an array of tubular elements having the same clampable length. It may be noted that if one were to fuse each translational bushing **88A**, **89A** with its nearest neighboring translational bushing **89A**, **88A**, and erase the intermediate bracket setting indicated by the dash-dot line **104**, the new schematic so generated would represent a preferred two-angle cambering arrangement such as that depicted in FIG. **5**. Correspondingly, providing additional translational bushings according to the scheme shown in FIG. **6** could provide the user with a choice of a greater number of camber angles.

The preferred embodiment **84** depicted in FIG. **5** also comprises an outboard nut **62**, an inboard bushing **66** and a clamping means **85**. The outboard nut **62** is affixed to the axle **28** at a predetermined standoff distance, S, from the hub **26**. The nut **62** provides an inboard-facing flange face **74** engaging the outer face **35** of the outboard bracket leg **20** in the uncambered setting and is preferably rotationally locked to the other tubular elements **30**. As will become clear in the following disclosure, the outboard nut's **62** function of providing a fixed outboard point for the clamping arrangement may be supplied by other equivalent structural elements (e.g., a collar shrunk or welded onto the outside of the axle tube **28**), all of which will be embraced by the term "nut" herein to set these elements off from other tubular elements **30** that can slide to and fro along the axle **28** and that are herein referred to as "bushings". The inboard bushing **66** provides a flange face **36** engaging the inboard face **37** of the inboard bracket leg **18** in the cambered setting and bearing on a mating flange surface **108** on a translational bushing **89** when the wheel **22** is uncambered. The inboard bushing **66** has an inboard-facing face **110** perpendicular to the axle **28** so as to conveniently engage a conventional washer, drive nut, or other clamping means **85** providing a clamping force along the axis of the axle **28**.

As stated supra, various vertical displacements can be accommodated either in the bracket leg or in the radial extent of the tubular elements **30**. In the embodiment **82** depicted in FIG. **4**, the bracket legs **18**, **20** have fixed and equal lengths. In the uncambered setting the legs **18**, **20** bear directly on the external surface of the axle tube **28**. In the cambered setting the legs **18**, **20** bear on radially displaced surface portions **140**, **142** of the middle bushing **92** and the inboard bushing **66**, respectively, and the surface portions **140**, **142** extend into cavities **146**, **148** in the outboard and inboard translational bushings **88**, **89**, respectively. Because the same bracket surfaces are used in both settings, it is preferred to provide an appropriately angled portion **144** of the radially displaced bearing surfaces **140**. **142** to ensure good contact in the cambered case. It will be understood that various modifications of the apparatus of FIG. **4** can be made. For example, if one chose to ignore the height change at the outboard bracket leg **20**, the leg **20** could be allowed to bear directly on the axle tube **28** in both settings, thus allowing the use of a smaller and lighter outboard translation bushing **88** and middle bushing **92**. Additionally, it is clear that the radially displaced bearing surfaces **140**, **142** could as well be made as part of the translational bushings **88**, **89**, with appropriate mating cavities **146**, **148** formed in the middle and inboard bushings. It is further noted that rotating the axle **28** and its associated array of tubular elements **30** through a half turn (a step necessary in the embodiment **60** depicted in FIG. **3**) is not required when using the embodiment **82**. Control of the rotational setting of the axle (as depicted in FIG. **3** by having the user place his or her thumb **90** on a portion of the axle **28** extending outward of the hub **26**), is needed in the embodiment **82** to ensure proper contact with the bracket legs **18**, **20**.

In another preferred embodiment **84** the changes in height at the bracket legs **18**, **20** are accommodated with a variable leg-length bracket **100**. One version of a variable leg-length bracket **100** is depicted in FIG. **7**. This bracket **100** comprises a cylindrical sleeve **150** affixed to the wheelchair frame **17** (e.g., by being welded to a plate **152** bolted to a mating plate (not illustrated) on the frame **17**) and a set of leg subassemblies **154**, **156**, each of which comprises a cylindrical member **158**, **160**, rotating within the sleeve **150**. The two leg subassemblies **154**, **156** are rotationally locked against independent rotation and may pivot together about the axis of the sleeve **150** among a plurality of settings, each of which corresponds to a different camber setting of the wheel system **22**. The variable bracket **100** can be locked into each of the predetermined camber settings by means such as the combination of a key **162** on the inboard bracket leg assembly **156** and a mating set of slots **164** on the sleeve **150**. Because the bearing surfaces **166A–166F** correspond to differing camber settings, each of the pairs (i.e., **166A**, **166D**; **166B**, **166E**; and **166C**, **166F**) bears on the axle tube **28** at a different predetermined angle. Hence, it is expected that the bearing surfaces **166**A–F will be cut at appropriate and differing angles. Although FIG. 7 depicts a bracket **100** having three pivotal settings, it is expected that two settings will be used in most cases which will reduce the fore and aft width of the legs **254**, **256** (i.e., as measured in a plane perpendicular to the axis of the sleeve **250**) and thereby reduce the clearance required for installing the pivoting bracket **100**.

It will be appreciated that a variety of other means of changing the length of a bracket (e.g., by inserting shims or tabs (not shown) into the bifurcated slots **54** of a fixed leg bracket **40**) may also be used in practicing the invention. One could, for example, use an inboard bracket leg **178** having two laterally-opening bifurcated slots **280**, **282**. In a leg **178** of this sort, as depicted in FIG. **8**, each slot **280**, **282** is associated uniquely with one of two camber angle settings. Although structurally simple, the minimum vertical displacement that can be provided with a dual-slotted leg **178** is greater than the minimum available with an adjustable leg bracket **100**. Because the vertical adjustment is larger, the bracket must be wider, and therefore the seat **24** must be wider to maintain adequate transverse clearance between the inboard ends of the right and left stub axles **28** (which are coaxial when a zero camber angle is selected).

An array of tubular elements **30** usable with a variable leg length bracket having two settings is depicted in FIG. **5**. In this depiction the outboard nut **62**, affixed to the axle **28** by a set screw **64**, comprises a stud **168** that mates either with a cut-out **170** in the outboard bracket legs **20** or with a keyway **171** in the outboard translation bushing **88**, the disposition of the stud **168** depending on the choice of camber setting. This stud **268** serves both to prevent the various tubular elements **30** from rotating together about the axle **28** when the cammed screw **172** or other clamping means **85** is tightened, and also to rotationally lock the outboard nut **62** to the outboard translation bushing **88**. A similar stud **168** on the inboard face of the outboard translation bushing **88** keeps the tubular elements **30** from rotating about the axle **28** during the clamping operation. In the depiction of FIG. **5** the various bushings **66**, **88**, **89**, **92** are rotationally locked by means of an extended key **174** affixed to the outboard translational bushing **88** and sliding within keyways **176** cut into the bottom of each of the other bushings **66**, **89**, **92**.

A desirable clamping means **85** operates without the use of separately carried tools and may comprise a cammed fastener using a camming lever rotatable within a through-hole (not shown) in the axle **28** to urge a cylindrical member against the inboard bracket leg **18**, e.g., as taught by Nicols et al. in U.S. Pat. No. 4,971,397, the disclosure of which is herein incorporated by reference. More conventionally, the clamping means **85** may be a deep-throated version of a well-known cammable fastener having a screw **172** engaging a nut **173** affixed within the hollow axle tube **28**. When the clamping fastener **85** is loosened, the various tubular elements **30** may optionally be urged slightly apart by a spring (not shown) so as to make it easier for the user to re-insert the wheel system **22** into the bracket **40** without being bothered by interferences.

When the clamping element **85** moves along the axle **28** it may apply a force to a bracket leg **18**, **20** that is not normal to one of the flange faces thereof. Moreover, because the preferred embodiments **82**, **84** comprise pluralities of bushings **88**, **88**A, **89**, **89**A, **92** clamped intermediate the legs of a bracket **40**, clamping in a cambered setting (i.e., when θ has a non-zero value) involves shearing forces intermediate ones of the bushings. Undesired slippage may be controlled by known expedients, such as providing corresponding tongue and groove elements on mating surfaces (not shown), by using robust keys **174** and keyways **176**, or by selecting appropriate clearances between the axle **28** and ones of the bushings **88**, **88**A, **89**, **89**A, **92**.

The bracket and retainer arrangements discussed supra provide the desired benefits of a selectable camber angle, as well as providing means of attaching a wheel system **22** to a chair **8** in which the exposed surfaces of the wheel system **22** are unlikely to be coated with a lubricant. Only small portions of lubricated surfaces, such as the outer surface of the axle **28**, are exposed to view and these are shielded from contact by adjacent flange faces.

Attaching a wheel **9** to a chair **8** using only the foregoing elements of the apparatus may require a good sense of balance or a third hand. Putting a wheel **9** on a chair **8** requires holding the frame **17** with one hand, picking up the wheel **9** (with due regard for rotational alignment of tubular elements **30**) with the other hand, inserting the axle **28** and tubular elements **30** into a bracket **40**, and balancing the frame **17** on the wheel **9** in order to free one hand to operate the clamping means **85**. A preferred embodiment provides a latch **112** adjacent the inboard bracket leg **18** to hold the wheel system **22** in place while moving one's hand from the wheel **9** to the nut **38**.

A latch **112**, as shown in FIG. **9**, may comprise a spring-biased hook **114** held in an axle-retaining position by a bias spring **116**. In this position the latch **112** can be used not only to hold the wheel system **22** in position during the wheel attachment operation, but can also serve as a safety mechanism retaining the axle **28** in an approximately correct attitude if the primary clamping means **85** becomes loosened. When the wheel system **22** is taken off an upright chair **8** (e.g., by loosening a capnut **38**, pushing the hook **114** away from the slot **54** and allowing the wheel system **22** to fall loose under the influence of gravity), the hook **114** is held against a stop **118**. When the wheel system **22** is subsequently to be reattached to the chair **8**, the user can turn the chair upside down, position the wheel system **22** to place an appropriate element **62**, **88** adjacent the outboard surface **35** of the outboard bracket leg **20** and then push the axle **28** and bushing **66** against the hook **114**, thus urging it away from the slot **54** (as indicated by the arrow **120** in FIG. **9**) and thereby allowing the axle **28** to slip into place for clamping.

Optionally, if one wishes to remove the wheel system **22** when the chair **8** is in an inverted position in which gravity will not dump the axle **28** out of the slot **54**, one may supply a latch hold-open mechanism, which may include a spring-biased trigger **122** shown in FIG. **9**, engaging a sear **124** in the locking hook **114** when the hook **114** is rotated into the open position indicated in phantom as **114***a* in FIG. **9**. The hook **114***a* can be released by manually rotating the trigger **122** against the force of its bias spring **128** in the direction indicated with arrow **130** in FIG. **9**.

Although one could provide a latch **112** adjacent either an inboard **18** or outboard **20** bracket leg, the preferred embodiment places the hook **114** adjacent the inboard leg **18**. The outboard bracket leg **20** serves as a fulcrum, or center of rotation, of the wheel system **22** about the bracket **20** both when the chair **8** is inverted and the system **22** is being clamped in place, and when the chair **8** is in use. Thus, a latch hook **114** adjacent the outboard leg **20** would be far less useful. One can, of course, make more complex latches with hooks **114** at both locations, or at intermediate locations.

Although the present invention has been described with respect to several preferred embodiments, many modifications and alterations can be made without departing from the invention. Accordingly, it is intended that all such modifications and alterations be considered as within the spirit and scope of the invention as defined in the attached claims.

What is desired to be secured by Letters Patent is:

1. Apparatus for attaching a wheel system comprising a wheel and a stub axle to a wheelchair at one of a plurality of camber angles, the apparatus comprising:

a bracket extending from the wheelchair, the bracket having inboard and outboard bifurcated legs, the length of one of the legs selectable from a plurality of predetermined leg lengths, each of the leg lengths respectively associated with one of the camber angles;

a plurality of tubular members juxtaposed along the axle, the tubular member closest to the wheel prohibited from sliding along the axle, the other tubular members slideably disposed on the axle;

a plurality of pairs of bracket-engaging faces, each of the pairs of bracket-engaging faces comprising respective exterior surface portions of two different ones of the tubular members, each of the pairs of faces tilted with respect to a line perpendicular to the axle by one of the predetermined camber angles; and

clamping means clamping the bracket legs between ones of the pairs of bracket-engaging faces.

2. Apparatus of claim 1 wherein the length of the inboard bifurcated leg is selectable from a first and a second length.

3. Apparatus of claim 1 wherein one of the tubular members comprises a bearing surface portion spaced a predetermined radial distance from the axle, the bearing surface portion interposed between one of the bracket legs and the axle when the wheel system is attached at a predetermined one of the camber angles.

4. Apparatus of claim 1 wherein the difference between two of the predetermined leg lengths is equal to an algebraic product formed by multiplying the tangent of the angular difference between the two respective camber angles by a width of the bracket.

5. Apparatus of claim 1 wherein

two of the tubular members have a predetermined axial length equal to a distance between a first point on the axle immediately below the outboard bracket leg when the wheel is attached at a first of the camber angles and a second point on the axle immediately below the outboard bracket leg when the wheel is attached at a second of the camber angles, and wherein

a clampable length between the bracket legs is equal to the sum of the predetermined axial length and an axial length of a third of the tubular members.

6. Apparatus of claim 1 wherein each of the bracket legs is separately clamped between one of the pairs of bracket-engaging faces.

7. Apparatus of claim 1 wherein the bracket comprises a cylindrical sleeve having a horizontal axis transverse to the wheelchair and wherein the leg having a selectable length comprises a tubular portion disposed within the sleeve for pivotal motion about the axis thereof, the leg further comprising two bearing surface portions, each of the two bearing surface portions spaced a respective one of the predetermined leg lengths from the axis of the sleeve.

8. Apparatus of claim 1 further comprising a latch, the latch comprising

a first rotatable latch member biased by a first latch spring into a latched position wherein the first latch member retains the axle within the bracket, the first latch member rotating into an open position wherein the first latch member does not retain the axle within the bracket, and

a second latch member biased by a second latch spring into a locked-open position wherein the second latch member coacts with the first latch member to hold the first latch member in the open position, the second latch member moving against the biasing force of the second latch spring to release the first latch member from the open position, the first latch member thereupon moving from the open to the latched position.

9. Apparatus attaching a wheel system comprising a wheel and a stub axle to a wheelchair at one of a plurality of predetermined camber angles, the apparatus comprising:

a bracket extending from the wheelchair, the bracket having inboard and outboard bifurcated legs;

a plurality of tubular members juxtaposed along the axle, the tubular member closest to the wheel prohibited from moving along the axis of the axle, the other tubular members slideably disposed on the axle, one of the tubular members comprising a bearing surface portion spaced a predetermined radial distance from the axle, the bearing surface portion interposed between one of the bracket legs and the axle when the wheel system is attached at a predetermined one of the camber angles;

a plurality of pairs of bracket-engaging faces, each of the pairs of bracket-engaging faces comprising respective exterior surface portions of two different ones of the tubular members, each of the pairs of faces tilted with respect to a line perpendicular to the axle by one of the predetermined camber angles, and clamping means clamping each of the bracket legs between ones of the pairs of bracket-engaging faces.

10. Apparatus of claim 9 wherein a second of the tubular members comprises a second bearing portion spaced a second predetermined radial distance from the axle, the second bearing surface interposed intermediate the axle and the other of the bracket legs when the wheel system is attached at the predetermined one of the camber angles.

11. Apparatus of claim 9 wherein each of the bracket legs is separately clamped between one of the pairs of bracket-engaging faces.

12. Apparatus of claim 9 wherein the length of one of the bracket legs is selectable from a plurality of predetermined leg lengths, each of the leg lengths associated with one of the camber angles.

13. Apparatus of claim 9 further comprising a latch, the latch comprising

a first rotatable latch member biased by a first latch spring into a latched position wherein the first latch member retains the axle within the bracket, the first latch member rotating into an open position wherein the first latch member does not retain the axle within the bracket, and

a second latch member biased by a second latch spring into a locked-open position wherein the second latch member coacts with the first latch member to hold the first latch member in the open position, the second latch member moving against the biasing force of the second latch spring to release the first latch member from the open position, the first latch member thereupon moving from the open to the latched position.

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